The telescope employed was 42 inches focal length and 2·6 inches aperture; power 50.

The time was got by equal altitudes of the sun on Feb. 1, and by an absolute altitude of both limbs on Feb. 2, with an eight-inch sextant by Troughton, and an oil horizon: the chronometer has a very steady rate.

Occultation of β *Scorpii* by the Moon, observed by R. Snow, Esq. at Ashurst, May 11, 1846:—

	Ashurst Sid. Time. h	m	s
Immersion of small star at moon's bright limb	15	39	37·5
—— large star ——	15	40	4
Emersion of large star at moon's dark limb	16	34	1
—— small star ——	16	34	41

The moon not far from full; in other respects the circumstances very favourable.

Ashurst Observatory. Latitude, 51° 15′ 58″ N.; Longitude, 1^m 10^s·1 West.

At the request of the Council, the Astronomer Royal gave an account of the measurement of an arc of longitude between Greenwich and the Island of Valentia, on the south-west coast of Ireland.*

The Astronomer Royal begun by stating that he had for many years intended to determine this arc of longitude, since such measurements are highly important in the investigation of the figure of the earth; and the configuration of the British Islands renders them peculiarly favourable for the purpose. The difference between the easternmost point of England and the westernmost point of Ireland is nearly 12° 12′ in longitude, and, what is very important, this greatest extent lies nearly in an arc of parallel. There is some room for choice as to the station on the west coast of Ireland, but, after a careful personal inspection, the Astronomer Royal selected a point in the Island of Valentia as the most appropriate. This point is a station in the trigonometrical survey, and, from the features of the country, apparently less liable to local disturbance than any other. It is in the vicinity of a harbour, which is now tolerably frequented, and may become more so; and it is nearly in the parallel of Harwich, itself also a seaport of importance. Besides these advantages, as the island of Valentia is the property and summer residence of the Right Hon. Maurice Fitzgerald, Knight of Kerry, that gentleman's countenance, assistance, and hospitality, were confidently reckoned upon, and, it need scarcely be added, as fully experienced. At present, that portion of the arc which lies between Valentia and Greenwich has been measured; the remainder of the

* A paper containing the detailed account of all the observations, computations, and results of this interesting work, was presented to the Society by the Astronomer Royal, and will be printed in the *Memoirs*, the Lords Commissioners of the Admiralty liberally defraying the expense. The satisfaction expressed by the members present with the lucid exposition of the Astronomer Royal, has induced the secretary to attempt to follow the lecture rather than to analyse the work itself according to the usual custom.

operation is delayed until the completion of railroad communication with Harwich.

Having selected Valentia as the western extremity, the first consideration was whether the longitude should be determined directly or by means of an intermediate point. Finally it was resolved that an intermediate station should be made at Kingstown, near Dublin, and for these reasons: that a smaller number of confidential persons would thus be required; that the links being less numerous, less risk of irregularity would be run, and with less consequent derangement; that a new and important point, Kingstown harbour, would be fixed (which is besides a point of easy junction with the Dublin Observatory); and finally, that from the nature of chronometrical changes, the chance of error in twenty-four hours is smaller than half the error in forty-eight hours. It was fully intended, however, that the same observer should remain during both measurements at Kingstown, by which the uncertainty of an additional personal equation would be avoided.

Before this point was agreed upon, the line from Greenwich to Bristol by rail, to Cork by steamboat, and from Cork to Valentia by mail or car, had been considered and abandoned, as well as another scheme, that of sending the chronometers all the way from Bristol to Valentia by sea. It is proper to say that the Lords of the Admiralty offered to place a steamboat at the disposal of the Astronomer Royal for this purpose, but on computing the time and probable uncertainty of so long a voyage, and the great expense which it would cause, the liberal offer of their lordships was not accepted.

It need scarcely be mentioned here, that the operation of measuring an arc of longitude, *chronometrically*, consists in these steps: the time is accurately determined at one end of the arc, Greenwich for instance, and the chronometers are carefully compared with the transit clock; hence the error of these chronometers on the meridian of Greenwich is known. These chronometers being carried to Kingstown, are then compared with a clock which is carefully rated by a transit instrument; thus the error of the chronometers on the meridian of Kingstown is known: but their error on Greenwich is also known if the *rate* be known, and the longitude is the difference of these two errors.

It is well understood by persons acquainted with the principles of mechanics, that the great difficulty in carrying chronometers without altering their going lies *chiefly* in preventing a rotatory motion in the plane of the balance. It is believed that box-chronometers are more susceptible of injury by carriage than pocket watches, and it is certain they take up more room. The Astronomer Royal on the whole concluded to use pocket chronometers, and borrowed 30 from different quarters. These were carefully packed in two cases, divided each into fifteen compartments, with springs under each chronometer, pressing it upwards, firmly but gently, against a padded lid. The sides and tops of each case were well wadded outside to protect them from any violence or jar. A number of boxes were

then made, each of which would just hold the two cases placed one above the other; and to every railway-carriage, steam-boat, or mail-coach, which did or could run along the line during the experiment, one of these boxes was screwed down, and a key was given to each confidential person employed. The course was this: The first assistant of the Royal Observatory, Mr. Main, compared each watch by *coincidences* with the Greenwich transit-clock, the cases were then put into a box and transported in an easy carriage in the care of one of the assistants of the Royal Observatory, avoiding the pavement as much as possible, to the Euston Square station, when the cases were transferred by him to the box already attached to the imperial of the mail. On the arrival of the mail at Liverpool, Mr. Hartnup, director of the Liverpool Observatory, and formerly assistant-secretary of this Society, was in waiting with a box and carriage, with which he transferred the cases to a box already fixed on board the steamer belonging to the City of Dublin Steam Packet Company. Mr. Sheepshanks, who had undertaken to make the transit observations and to compare the chronometers at Kingstown, was in readiness to take the chronometers when the steamer arrived, and it was his business to wind up the chronometers, compare them, and return them by steamer that evening. Mr. Hartnup again conveyed the cases, with the same precaution as before, to the morning mail at Liverpool, and they were received at Euston Square and taken back to Greenwich by one of the assistants, where they were compared by Mr. Main. Thus the chronometers which left Greenwich on the morning of the 1st were brought back on the evening of the 3d, and were again despatched on the morning of the 4th.

The two comparisons of the morning of the 1st and the evening of the 3d give a rate for each chronometer for the whole interval, which is pretty nearly, though not exactly, halved by the comparison at Kingstown. Again, the errors at Kingstown on the 2nd and 5th days furnish a rate which will generally differ somewhat from the rate obtained by the Greenwich observations. Also, it was found, that notwithstanding all the precautions used, there is a difference of rate in the same chronometer according as it is travelling or at rest, and the error on Greenwich time at the time of the Kingstown comparison was calculated with a reference to this difference. The Astronomer Royal has investigated what he considers to be the *most probable* rate upon the data afforded, for which discussion the Memoir itself must be referred to.

It has already been mentioned that Mr. Sheepshanks took charge of the Kingstown station. A small observatory had been erected here under the direction of Lieut. Leach, R.E., upon the plan of the Astronomer Royal; the Harbour Master, Lieut. Hutchinson, R.N., very kindly allowing a site in his garden and a passage through his grounds. The building was chiefly remarkable from having the slit *along* the ridge of the building, instead of *across* it; a construction already adopted by the Astronomer Royal for the temporary observatory used by M. Struve in determining the arc between Greenwich and Pulkowa, and which is both com-

pact and convenient. A solid pier was carried up from the rock about 30 inches above the floor, and covered by a thick slab of stone. The stone piers, truncated cones, so heavy as to be moved by one man with difficulty, were cemented on the slab, and a very excellent $3\frac{1}{2}$ foot transit, the property of Mr. Sheepshanks, placed upon them. A rail round the pier enabled the observer to support himself conveniently while observing any star up to 50° or 55° altitude; and by a contrivance which, though convenient, does not merit any particular description, the observer could command any star without employing a diagonal eye-piece. A pretty good transit clock, also the property of Mr. Sheepshanks, was fixed in an angle of the building; and, on the whole, it may be said, the means of getting the time were nearly, if not quite, as accurate as those of a first-rate observatory.

The first method of observing, as proposed by Mr. Sheepshanks, —and, indeed, necessarily practised for some time—was to observe in *one position of the instrument* several stars, and at least one star near the pole, to apply the level at least four times, to *reverse the instrument*, to apply the level as before, and then to observe a circumpolar star, and as many equatorial stars as were considered necessary. The error of collimation to be used in the reductions is that which gives the same clock error (allowing for rate) to each set. There are, however, considerable objections to this method, especially in uncertain weather; and at the request of the Astronomer Royal, Mr. Sheepshanks set up a north collimating mark, which fortunately the situation allowed. A block of stone was cemented on the wall of the northern pier of Kingstown harbour, and on this block was again cemented a piece of black marble, with the edge bevelled upwards at an angle of 45°. A round disc of white marble, nicely let into the black marble, made a very good mark, and though the distance ($\frac{2}{3}$ of a mile) was rather too close, yet a moderate limitation of the aperture of the telescope rendered the bisection pretty satisfactory. In practice, the adjusting screws were very seldom used, and the error of collimation being small, the observer either described or drew the appearance of the bisection in both positions of the instrument every evening before commencing his operations. The results are said by the Astronomer Royal to be highly satisfactory, and more consistent than those obtained by Mr. Sheepshanks while following the first method.*

As the uncertainties of climate are even greater in Ireland than in England, and the transit-clock, though a good one, not of the very highest class, and moreover liable to some suspicion from

* In a *complete* set of observations, the difference of the two methods for getting the time is inconsiderable, as the *mean* of the times will come out nearly the same with very differently assumed collimation errors. But the advantage of a collimating mark is, that it gives a good collimation error at all times, and *therefore* sufficient data for getting the time *without* reversal; and that if the meridian error of the mark be well known from the whole mass of observations, the broken and indifferent sets will still yield a respectable clock error. It will be seen these remarks apply most forcibly to situations and purposes like those of the Kingstown and Valentia Observatories.

its imperfect fixing, Mr. Sheepshanks felt great apprehension that he should not be able to carry on the time from observation to the comparison of the chronometers. He took, therefore, with him to Kingstown, every supplementary time-keeper in his possession, each of which was compared directly or indirectly with the transit-clock at every epoch of observation, and at every epoch of comparison with the chronometers. This precaution, though it greatly increased the trouble of observation and computation, has also added considerably to the accuracy of the result, for the weakest point is evidently the carrying on the time between the epochs of observing and comparing, which may be one or two days in unfavourable weather.

Although the time of comparison at Kingstown was tolerably near the middle time between the arrival and departure of the chronometers, it was found necessary, as has been stated above, to make a small correction for the inequality of time and the difference of travelling and stationary rates. It would have been better that one set of comparisons should have been made on receiving the chronometers, and a second set just before returning them, and this course was recommended by the Astromomer Royal; but the fatigue of these comparisons was so great, owing to the number of watches, the badness of their markings, and the variety in their beats, and also the danger of hurry so great, that, on the whole, Mr. Sheepshanks contented himself with one series, each of three careful comparisons.*

Before the Greenwich-Kingstown series was completed, an attack of rheumatism in the knee compelled Mr. Sheepshanks to apply for a substitute. Mr. Hind, then of the Royal Observatory, and now director of Mr. Bishop's observatory, was sent to supply his place. This unforeseen accident deranged one of the original dispositions, viz. that the Kingstown observer should be one and the same during the whole series. Some delay had taken place in communicating with Lieut. Gosset, R.E. (the officer who was selected by Col. Colby to take charge of the Valentia station), and this spare time was employed in running the chronometers between Kingstown and Liverpool. The weather during the measurement of the Liverpool-Kingstown arc was very unfavourable.

In the mean time Lieut. Gosset and Mr. Sheepshanks proceeded to the island of Valentia, to arrange proceedings and to set up the transit instrument. There is a mail every evening from Dublin to Limerick, continued to Tralee with a change of carriage. From thence to Cahirsiveen, the usual conveyance seemed too slow and

* Most of the watches beat 5 times in 2 seconds, which gives a coincidence at every 36 seconds with a half-second sidereal chronometer. In some of these the second-hand corresponded with the even second, in others with the odd second. A few watches beat 8 times in 3 seconds. Some rude pen scratches were made to correct the error of the divisions of the seconds' circle. The sidereal chronometer was compared *directly* with the stationary solar chronometers, and through these *indirectly* with the transit-clock and another reserve-clock, before and after the comparisons. It is conceived that the errors of comparison could scarcely amount to a thirtieth of a second in each travelling chronometer.

uncertain, and arrangements were made by the Astronomer Royal with Mr. Bianconi, to furnish an especial car and relays for this part of the journey. The ferry at Valentia was then to be crossed, and the chronometers carried by hand about four miles to the summit of a hill, a station in the trigonometrical survey, and the site of the observatory.

The process of transporting the chronometers was as follows:— By permission of James Cumming, Esq., Inspector of Mail-coaches for Ireland, boxes exactly similar to those already mentioned, were screwed on all the Limerick and Tralee mail coaches, and Mr. Hind, after comparing the watches at Kingstown, carried the cases containing them to Dublin, placed them in the box attached to the Limerick mail, and locked them up. At Limerick, a trustworthy private of the corps of Sappers and Miners removed the cases from the box on the Limerick to the box on the Tralee mail, which he then mounted and accompanied to Tralee.* At Tralee he was joined by a companion of the same corps, and together they wound up the watches as they had been previously taught, holding the watch motionless in the left hand, while winding with the right. The cases were then placed in a box tightly wedged with mats in the well of an Irish car, and posted to Cahirsiveen, under the charge of the sapper. At Cahirsiveen, the cases and their guardian were carried over the ferry by Mr. Quadling, Superintendant of the Coast Guard on that station, and were usually lodged at the inn there till daylight,† when the cases were carried in their box, one man before and another behind, like a sedan-chair, to the camp and observatory at Feagh Main, the Valentia station. Here they were compared by Lieut. Gosset with his transit-clock.

The chronometers were returned the same evening in a similar manner to Cahirsiveen, posted thence by car to Tralee, where they were again wound up and placed by Private Penton, first on the Tralee, then on the Limerick mail, and received at Dublin, by Mr. Hind in the morning, to be returned in the evening as before described.

The transit-room at Valentia was about 900 feet above the sea, and removed a little from the trigonometrical station, in order to view a south mark placed on the sea-beach. A mark had already been set up by a former observer, but it was too insecurely fixed to be relied on. A rough observation having determined the approximate error of this mark, a second mark was erected, but

* Private Penton was stationed at Limerick for this duty. He had previously assisted Mr Sheepshanks at Kingstown, and performed every thing committed to him with great zeal and intelligence.

† It was intended at first to carry the chronometers immediately on their landing, to the camp; but the risk of injury over a rough road in the dark induced Mr. Sheepshanks to change the original arrangement. Lieutenant Gosset's party was besides so weak, and had suffered so much from exposure and fatigue in erecting the observatory, that it was not thought prudent to break their rest without absolute necessity. In two instances, however, the chronometers were at once carried to the observatory and immediately compared with the transit clock.

only by guess, as there were no means for measurement and no time for a careful determination. All the visible line from the observatory was ascertained to be bog down to the sea-shore. Under these circumstances, Mr. Sheepshanks adopted the following construction, as best adapted to the circumstances:—A square flag of Valentia slate, about four feet long and broad, and above six inches thick, was laid horizontally on the sand which covers the beach a little above high water. An upright post of slate, about 3 feet high, and 12 inches by 15 in section, was let into this flag, and a square trench about four inches wide and deep cut in the direction of the meridian along the top of it. A strong plate of metal with a square aperture was let into this trench cross-wise, and the aperture formed the meridian mark. The light reflected from the sky by the sea was very sharply seen by day, and at night, a Sapper kept a lighted lamp behind it. As a collimating mark, nothing could have answered better, and it seems from the observations that it was sufficiently steady as a point of reference.*

Two large upright blocks of Valentia slate formed the supports of the transit. It had been intended to follow the same plan as at Kingstown, but from some misunderstanding the large blocks were cut first, and Lieut. Gosset preferred being able to stand between the piers. The great danger of tall piers is, that, unless enormously massive, they are liable to twist; but this failing does not seem to have occurred at Valentia.†

Lieut. Gosset was requested to bisect the mark and to apply the level before observing, and when a tolerable set of transits had been taken, then to apply the level, to reverse, and to note very carefully the appearance of the mark; then to bisect the mark, to apply the level again, and to make a second set of observations. The depression of the mark was so great as to require great attention to the level while estimating or measuring the error of collimation. The object-glass of the transit is remarkably good (by Fraunhofer), and quite sufficient for a most accurate determination of time, though only 30 inches focal length, and 2·6 inches aperture.‡ Notwithstanding the uncertainty of the weather, which scarcely ever allowed all the 7 wires to be observed, the observations for time were perfectly satisfactory, thanks to the keenness of the observer and the precautions which have been described. To preserve the time an additional clock and chronometer were used.

To complete the series of determined longitudes, the chronometers were finally transported directly from Greenwich to Li-

* The winding channel which separates the island of Valentia from the mainland, and on the shore of which the mark was placed, is not, in ordinary weather, liable to any considerable agitation.

† It would have been impossible to get work of this nature executed at such short notice, if at all, unless the proprietor of the slate-works, B. Blackburn, Esq., had taken the matter personally on himself and in the most obliging manner.

‡ This instrument is the property of Mr. Sheepshanks, and is figured and described in the *Penny Cyclopædia*, article TRANSIT.

verpool and back again several times. The partial arcs determined are, Greenwich - Liverpool, Liverpool - Kingstown, Greenwich - Kingstown, Kingstown - Valentia.

Considering the complication of the journey, the number of steps to be taken, and the different persons and conveyances to be employed, it is remarkable with what regularity every thing went on. A good deal of this is due, no doubt, to the careful previous arrangement of the Astronomer Royal; but such was the zeal and punctuality of the agents, and the kindness and liberality of the different railroad, steamboat, and mail-coach companies, and of the general and local authorities, that no stoppage whatever took place, except the little delay caused by Mr. Sheepshanks' illness; and the Astronomer Royal expressed his conviction that a sovereign, however absolute, could scarcely have had more control over any operation than he had over this.*

The error of the transit-clock at Greenwich at the times of comparison was computed in the usual manner. At Kingstown and Valentia the other timekeepers were introduced to correct the clock; and at Liverpool Mr. Hartnup checked his transit-clock by his mean time-clock in the adjacent chronometer-room.

Each chronometer, after the proper rate and other reductions have been applied, gives a difference of longitude between the two stations for every trip from one to the other; the mean of which differences is the result due to that chronometer. A comparison of the rates during each journey gives the *weight* of such result, and the mean of the whole was taken with reference to those weights.

In this way the following differences of longitude were obtained:

	m	s		s
Greenwich-Liverpool	11	59·886	Probable error	±0·0102
Liverpool-Kingstown	12	31·322	——	±0·0164
Greenwich-Kingstown	24	31·097	——	±0·0138
Kingstown-Valentia	16	51·992	——	±0·0129

These results are not freed from the effect of personal equation. Account has been taken of the difference between the stationary and travelling rates. It seems that the pocket chronometers lost in travelling about $0^s.7$ per day on their stationary rates; this quantity is, perhaps, somewhat less in railway travelling.

At Greenwich the observations are either made by Mr. Henry or reduced to him by the known difference between him and the other observers. The Liverpool observations are by Mr. Hartnup; the Kingstown observations are partly by Mr. Sheepshanks and partly by Mr. Hind, and are reduced to Mr. Hind by the personal equation determined at Kingstown. Lieut. Gosset made the observations at Valentia. It will be seen that the sum of the partial arcs between

* Particular thanks are due to Richard Creed, Esq., H. P. Bruyères, Esq., and Captain Huish, of the Birmingham and Grand Junction Railways; to Mr. Hartnup; to Charles Williams, Esq., of the City of Dublin Steam Packet Company; to the Post-Office authorities; to Mr. Bianconi; to Sir James Dombrain, Inspector of Coast-Guard, and to Mr. Quadling.

Greenwich and Kingstown exceeds the direct determination by $0^s.111$. The Astronomer Royal conceives that the results may best be made to agree by subtracting $0^s.028$ from the Greenwich-Liverpool, subtracting $0^s.056$ from the Liverpool-Kingstown, and adding $0^s.028$ to the Greenwich-Kingstown arcs. Hence

		m	s
Liverpool,	west of Greenwich	11	59.858
Kingstown,	west of Liverpool	12	31.267
——	west of Greenwich.....	24	31.125
Valentia,	west of Greenwich.....	41	23.117

in which the errors can scarcely exceed $0^s.03$ or $0^\circ.04$, independent of the error of personal equation.

The personal equations which have been used in the final reduction of the longitudes are as follows:—

By a comparison of stars observed on December 5, 1844,* by Mr. Henry and Mr. Sheepshanks, and expressing the result by the usual equation, in which the initial of the observer's name is used to denote the "clock slow," resulting from his observation, it was found

$$S - He = +0^s.404$$

Observations at Liverpool between Mr. Hartnup and Mr. Sheepshanks on December 6, 1844, gave the equation

$$S - Ha = +0^s.21$$

Hence we have the equation

$$Ha - He = +0^s.19$$

the quantity which is to be added to the west longitude of Liverpool, as given by observation, to correct it for the personal equation of the observers.†

The personal equation between Mr. Sheepshanks and Mr. Hind, determined pretty carefully at Kingstown, is expressed by the equation

$$S - Hi = +0^s.33$$

* Many comparisons have been made between Mr. Henry and Mr. Sheepshanks at different times, and the results, when a sufficient number of stars has been observed, have generally fallen between $0^s.3$ and $0^s.4$, Mr. Sheepshanks noting the transit of the star so much *earlier* than Mr. Henry.

† This result is liable to some doubt. The observations of Dec. 6 were very indifferent; the night was unfavourable; there was a good deal of annoyance from noise; and Mr. Sheepshanks was, perhaps, hurried, having travelled all day, and being worried by the inconveniences just mentioned. Earlier comparisons with Mr. Hartnup give $S - Ha = 0^s.05$ at the most, and some very careful and accordant observations made within the last few weeks, give $S - Ha = 0^s.22$. It is pretty clear that one of the two observers has varied in his mode of observing. Perhaps the true longitude of Liverpool may be safely assumed to be between $12^m\ 0^s.0$ and $12^m\ 0^s.1$. A previous determination by Mr. Sheepshanks made the longitude $12^m\ 0^s.24$; but though the *time* was got by him at both stations and the personal equation thus eluded, yet there was but one trip to and fro. The *stationary* rate too was used in the reductions, and he had only his own chronometers.

which, combined with the first equation, gives

$$Hi - He = +0^{s}\cdot07$$

the quantity to be added to the west longitude of Kingstown.

The personal equation between Lieut. Gosset and Mr. Sheepshanks at Kingstown and Valentia was found to be

$$S - G = +0^{s}\cdot29$$

whence

$$G - He = +0^{s}\cdot11$$

by which the west longitude of Valentia is to be increased.* Hence the final results are

	m	s	
Longitude of Liverpool	12	0·05	West.
—— Kingstown	24	31·20	
—— Valentia	41	23·23	

Mr. Airy, after giving the different data on which the estimation of this error is founded, says, "that they tend to shew that the proportion of uncertainty as depending on personal equation to uncertainty as depending on transmission of chronometers is greater than is generally supposed." Indeed, it appears that, when a tolerable number of chronometers is used for a moderate distance and in good observing weather, the *variation* of personal equation is the error to be most feared.

After obtaining these *absolute* values of the arcs of longitude, freed so far as is possible from all known causes of error, and undoubtedly a very close approximation to the truth; it is necessary to compare the results with the data of the trigonometrical survey, and to see how far they agree with the best existing determinations of the figure of the earth.

The triangulation of the Ordnance Survey had been so far extended as to connect the four stations of Greenwich, Liverpool, Kingstown, and Valentia (some triangles having been formed by Colonel Colby expressly for this purpose); the lengths of all the sides had been computed; and the absolute azimuths of several lines had been determined by observations of the Pole-star at some of the stations of the survey. These data cannot be used for a comparison of the geodetic and the chronometric determinations without an approximate knowledge of the figure of the earth. It is necessary to take elements very near to the truth; with these to

* There were some direct comparisons made at Greenwich between Mr. Hind and Messrs. Main and Henry, the results of which are rather discordant, and some observations were made by Lieut. Gosset, while in training at Greenwich, which would considerably increase the value of $G - He$. But this was before Lieut. Gosset was in full practice; and it seems that observers have a tendency at first to observe a little *earlier* than after some experience.

calculate from the lengths and directions of the sides of the triangles, the difference of longitude of the several stations; and to compare this difference of longitude with the chronometrical difference of longitude, and thus to discover whether it is necessary to make any alteration in the assumed value of that element which is principally concerned here, namely, the radius of a parallel in the latitude in which these observations are made. The difference of longitude, as inferred from the triangulation, must be deduced step by step, by calculating the longitude of the second survey-station from the first, that of the third from the second, and so on. Now, at the first station (Greenwich) the absolute azimuth of the second station, as seen from the first, was known; but at the second station the absolute azimuth of the third was not known; and, therefore, it was necessary to compute the absolute azimuth of the first station as seen from the second; and applying to this the horizontal angle as observed at the second, to infer from it the absolute azimuth of the third as seen from the second. Besides this, it was necessary to know the latitude of the second station, in order to make the computations from the second to the third; but as the latitude of the second was not observed, it must be computed from that of the first. Thus the problem which at every step must be solved is this: Given the dimensions of the spheroid, the latitude of the first station, and the distance and bearing of the second station, to compute the latitude of the second station, its difference of longitude, and the bearing of the first as seen from the second.

The accurate equations applying to this problem are so complicated that it is necessary to seek simple approximate equations of sufficient accuracy. Several methods were tried, suggested by a consideration of the geometrical circumstances affecting their accuracy. The test was this: the largest triangles of the survey were taken, and in each starting from one angle, the calculation was carried through the three sides so as to return to the same angle, and the process was then only considered satisfactory when it reproduced the original latitude, longitude, and azimuth, without sensible error. It was found that this result was obtained when the calculation was made by the rules of spherical trigonometry, the radius of the sphere being assumed to be the normal (as terminated by the earth's axis of revolution) to the first station in each line to be computed; the resulting difference of longitude was then to be used unaltered, and the resulting difference of latitude was to be altered in the proportion of the radius of curvature in the middle of the arc of latitude to the normal defined as is stated above.

The elements of the terrestrial spheroid which for several years have been used in the calculations of the Ordnance Survey Office, are those given by Mr. Airy, in the article *Figure of the Earth*, in the *Encyclopædia Metropolitana*, namely,

Polar semi-axis...	20853810 feet
Equatorial semi-axis.....	20923713 feet

and the longitudes computed with these elements from the triangulation are—

	m	s
Geodetic longitude of Liverpool	12	0·35
—— Kingstown	24	31·48
—— Valentia.....	41	23·07

The two first of these are larger than the chronometrical values, and the third is smaller.* If we consider separately the three sections, Greenwich-Liverpool, Liverpool-Kingstown, Kingstown-Valentia, the geodetic value for the first is larger than the chronometrical value, while for the third it is smaller, and for the second they are sensibly equal.

The general result appears to be, that no sensible improvement can be made in the value of the radius of parallel given by the elements stated above; and thus we may assume, as a well-established element for the figure of the earth, that in the latitude, 51° 40′, the length of 1″ in an arc perpendicular to the meridian is 101·6499 feet, in terms of the standard bar of the Ordnance Survey.

* These computations were under the direction of Capt. Yolland, F.R.A.S. of the Ordnance Survey, and communicated by him to the Astronomer Royal.

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